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A high-efficiency repetitively pulsed magnetically insulated transmission line oscillator

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A B S T R A C T

A high-efficiency repetitively pulsed magnetically insulated transmission line oscillator (HERP-MILO) is presented in this paper. In the HERP-MILO device, there are three improvements. Firstly, a focusing electrode is introduced to enhance the power efficiency. Secondly, an array of round holes is added to the outer circumference of slow wave structure (SWS), which can enhance the flow conductance in the beam-wave interaction area through the way of exhausting radially. Thirdly, an auxiliary vacuum cell is introduced round the SWS, and there are 6 vacuum pump ports in the auxiliary vacuum cell. The auxiliary vacuum cell helps to inhibit the excessive pressure growth in the beam-wave interaction area during the HERP-MILO operation, and the 6 vacuum pump ports can enhance the vacuum pumping speed and efficiently reduce the vacuum recovery time. The simulation and experimental results show that the focusing electrode is effective to enhance the power efficiency. Moreover, the experimental results also show that the array of round holes and the auxiliary vacuum cell can improve the vacuum condition of the HERP-MILO, which is favorable for the increase of the duty cycle, the pulse repetition rate and the cathode lifetime of the HERP-MILO.

1. Introduction

The magnetically insulated transmission line oscillator (MILO) is a promising high power microwave (HPM) source and major hot-spot in the field of HPM research, whose advantages include its high power output, stable operation, self-magnetic insulation, and compact configuration [1–26]. However, because of the fact that a large fraction of the dc input current forms the load current, its power efficiency, which can be given by the output microwave power divided by the product of the diode voltage and the total anode current, is not very high for most applications [1–26]. Furthermore, because of the outgassing of the velvet cathode, the duty cycle, the pulse repetition rate, the maximum burst duration, and the cathode lifetime can be limited by the poor vacuum condition [21–25]. To enhance the power efficiency of MILO and improve the vacuum condition during the repetition rate operation, this paper presents a high-efficiency repetitively pulsed MILO (HERP-MILO).

2. Design of the structure

The structure of the HERP-MILO is as Fig. 1. The interaction region of the HERP-MILO can be treated as a diode, which comprises a cathode and an anode. The anode includes the slow wave structure (SWS), the beam dump, etc. The basic principle of the MILO can be described as follows [10]. A high-voltage pulse is introduced from the left in Fig. 1. Electrons are emitted as field emission from the cathode. The part electrons emitted from the end of the cathode generate the dc magnetic field, which prevents electrons emitted on the cathode in the SWS section from reaching the anode. The dc magnetic field plays a key role in the synchronism between the drifting electrons and a certain electromagnetic wave, whose characteristics are determined by the slow wave structure (SWS), transferring energy from the electron beam to the electromagnetic wave. The growing electromagnetic wave induces an RF voltage across the extractor gap which produces a transverse electromagnetic (TEM) wave in the coaxial section around the beam dump. The TEM wave propagates down the section of coaxial waveguide and is transformed into the TM_{01} mode by a mode converter, which is then radiated from a horn antenna into air.

Compared with previous improved MILO [8,10,11,17,19,22], there are three improvements in the HERP-MILO. Firstly, a focusing

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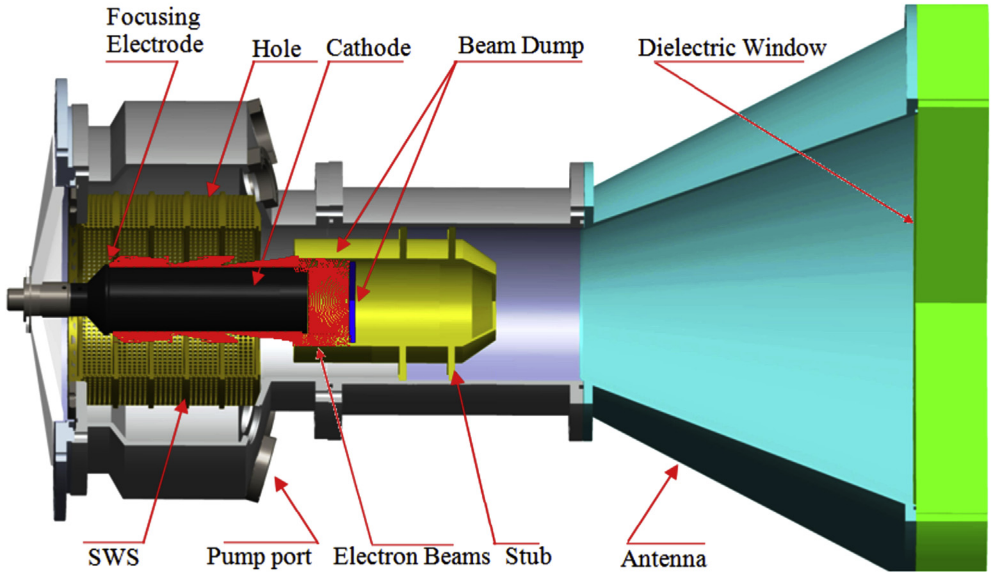

Fig. 1. Configuration of the HERP-MILO.

electrode is introduced to enhance the power efficiency and minimize anode plasma. On the one hand, the focusing electrode can contribute to guide the electron beam closer to the slow-wave structure and thus to enhance the beam-wave interaction, so the power efficiency is enhanced. On the other hand, the focusing electrode on the end of the cathode helps to control the beam current density, and hence, to minimize anode plasma, which has been validated by the simulation and experimental results [16]. Secondly, an array of round holes is added to the outer circumference of slow wave structure (SWS), which can enhance the flow conductance in the beam-wave interaction area through the way of exhausting radially. Thirdly, an auxiliary vacuum cell is introduced round the SWS, and there are 6 vacuum pump ports in the auxiliary vacuum cell. The array of round holes and the auxiliary vacuum cell can improve the vacuum condition during the repetition rate operation.

3. Simulation and analysis

To confirm the effect of the focusing electrode on the power efficiency, the HERP-MILO is investigated numerically using particle-in-cell (PIC) method with the 2.5-D fully electromagnetic CHIPIC code [27]. In simulation, high-power microwave is generated with peak power of 2.95 GW at an efficiency of 17.8%, frequency of 1.567 GHz, when the voltage is 420 kV and the current is 39.5 kA. In simulation, the waveforms of the applied diode voltage and current have 20 ns rise time, 20 ns duration and 20 ns fall time respectively. In this way, the input power is about 16.6 GW.

Fig. 2 describes the comparison of output power. With the focusing electrode, the output microwave peak power is 2.95 GW and the corresponding maximum power efficiency is 17.8%.Keeping the input powers same and taking away the focusing electrode, the output microwave peak power is 2.36 GW and the corresponding maximum power efficiency is 14.2%.So, the power efficiency has an increase of 25% because of the introduction of the focusing electrode. The comparative results indicate that the focusing electrode helps to enhance the power efficiency of the HERP-MILO. The reason is likely that the focusing electrode can contribute to guide the electron beam closer to the slow-wave structure and thus to enhance the beam-wave interaction, so the power efficiency is enhanced.

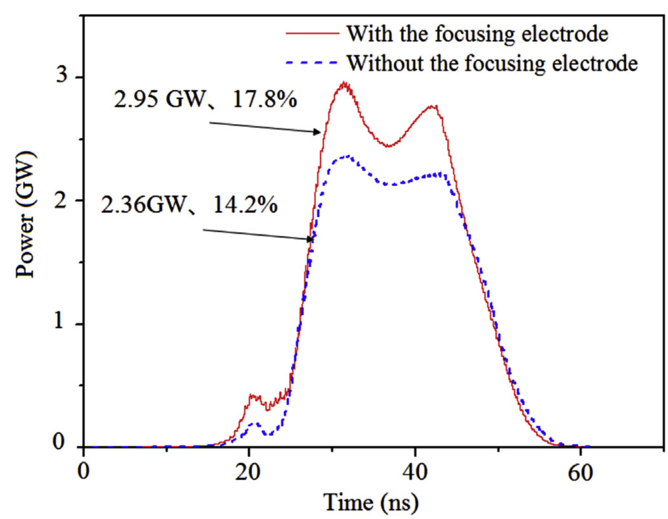

Fig. 2. Output microwave power versus time.

Fig. 3 illustrates the frequency spectrum of the HERP-MILO with the focusing electrode. The dominant frequency is 1.567 GHz. The

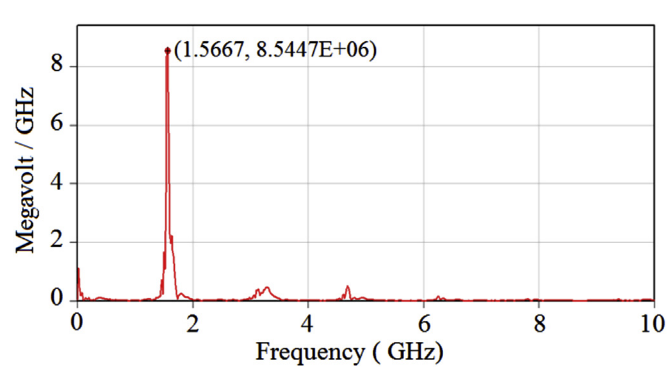

Fig. 3. Fourier spectrum of the signal.